Section 2
Environmental Setting

The waterways comprising the Calcasieu Estuary have been modified substantially to accommodate the demands of modern civilization. An analysis of the land-use patterns in southwestern Calcasieu Parish displays the close association among the urban, industrial, and agricultural users and the surface water system. An aerial survey of the region reveals a labyrinth of gullies, ditches, canals, bayous, channels, lakes, marshes, and ponds–all ultimately connected to the Calcasieu Estuary (DeRouen and Stevenson 1987).

The estuary is the lower portion of the Calcasieu River drainage basin. The Calcasieu River begins in the hills west of Alexandria (in the vicinity of Kisatchie National Forest in Vernon Parish, LA, approximately 120 km to the northeast), and flows south into Calcasieu Lake, eventually emptying to the Gulf of Mexico (Figure 2-1). Because of the geographic extent of the Calcasieu Estuary, it has been divided into areas of concern (AOCs) for the purpose of this discussion (Figure 2-2). The four AOCs include:

- Bayou Verdine
- Bayou d'Inde
- Upper Calcasieu
- Lower Calcasieu

Key geographic features in the estuary and of primary interest are the ship channel (the portion from I-10 bridge through Moss Lake), Bayou Verdine, Bayou d'Inde, Lake Charles, Lockport Marsh, Contraband Bayou, Prien Lake, Indian Marais Lagoon, Moss Lake and Bayou Olsen (Figure 2-2). In addition, several reference areas have been identified. Reference areas are locations that have physical settings similar to an AOC but lack significant anthropogenic impacts (e.g., industrial discharges). Reference areas may also be considered background areas. Reference areas for the RI include Willow Bayou, Johnsons Bayou, Bayou Bois Connine, Grand Bayou, and Bayou Choupique (Figure 2-1). Further details on the AOCs, including key geographic features, are provided in this section and in Sections 7 through 10. The reference areas are evaluated in Section 6.

2.1 Physiographic Features

Calcasieu Estuary is located within the West Gulf Coastal Plain physiographic province. This plain, west of the Mississippi Alluvial Plain, occupies the western half of Louisiana. Hilly regions, often with steep bluffs 25 m high, mark the transitional zone between this region and the Mississippi Alluvial Plain. The local area is comprised of geologically young unconsolidated Quaternary (Pleistocene-age)

sediments (Figures 2-3). Structurally, the area is a geosyncline that receives large quantities of sediment from multiple river discharges (Louisiana Geological Survey [LGS] 1984).

The northern and north central portions of the West Gulf Coastal Plain are primarily areas of rolling hill country, much of it heavily forested. The southern end consists of extensive areas of prairie grasslands. These grasslands lie along the middle course of the Calcasieu River. In the southern part of the West Gulf Coastal Plain, marshlands rim the coast and extend inland as much as 30 km. They are generally separated from the Gulf by low sandy ridges referred to as the Louisiana Chenier Plain. The Chenier Plain predominates the area south of the Intracoastal Waterway. The Chenier Plain is south of the RI area of interest; it is referenced to complete the discussion on physiographic setting.

The Chenier Plain extends from the western bank of the Freshwater Bayou Canal located in the Vermilion-Teche basin in southern Louisiana westward to the Louisiana-Texas state border, from the Intracoastal Waterway to the north to the Gulf of Mexico. Deltaic mud deposited in the area by the Mississippi River 3,000 to 4,000 years ago underwent erosion and was reworked, creating the gulf shoreline beach ridges known as Cheniers. Over time, shifting of the Mississippi channel from east to west resulted in the shore-parallel ridge and swale topography that comprises the Chenier Plain. Intermediate to brackish marshes, bayous, and lakes characterize the plain Louisiana Department of Natural Resources ([LDNR] 2002).

2.2 Geology and Soils

As noted, the southwest Louisiana area is comprised of geologically young, unconsolidated Quaternary (Pleistocene-age) sediments. They are Pleistocene-age terraces deposited on the Gulf Costal Plain during glacial retreats (LGS 1984). The Pleistocene surface is characterized by a series of entrenched valleys, which are separated by broad, gently rolling divides. An illustrated geological history of the development and the filling of the Calcasieu entrenched valley system (derived from the LeBlanc 1949 study) is provided in Figure 2-4.

These sediments are typically composed of interbedded sands, gravels, silts, and clays. Four distinct terrace deposits have been identified in Calcasieu Parish: the Williana, Bentley, Montgomery, and Prairie.

The surficial deposits in the Lake Charles area are clays, silts, fine sand, and shells of the Prairie Terrace (LGS 1984). The Prairie Terrace varies in elevation from approximately 20 feet in the latitude of Lake Charles to about 2 to 3 feet in the latitude of Hackberry Ridge (Calcasieu Lake and points south, Figure 2-3), where the terrace passes under the recent marshland deposits (LeBlanc 1949). The gradient of the Prairie Terrace slopes toward the Gulf of Mexico at a mean declination of 0.2 meters per kilometer (m/km).

The Pleistocene terrace deposits include the 200, 500, and 700-foot sands that comprise the Chicot aquifer that underlies the site. These units generally thicken with depth toward the south. Faulting associated with local Lockport and Sulphur Mines piercement salt domes cause local variations in thickness and dip.

Shallow groundwater is present in the Calcasieu drainage basin and occurs in similarly named units; the 10-foot, 20-foot, 30-foot, 50-foot, and 70-foot sands. These shallow units are typically interbedded and interconnected. The nomeclature is relative; the depth that the units occur is generally within 100 feet of the ground surface (IT Corporation 1995).

In some locations, the Pleistocene terrace deposits may be overlain by Holocene alluvium consisting of sandy and gravelly channel deposits mantled by sandy to muddy natural levee deposits, with organic-rich muddy backswamp deposits in between them (LGS 1999). The local soils consist of Basile and Guyton silt loams. These soils are frequently flooded, low permeability, poorly drained silt loams (LGS 1984). Previous investigations within the estuary (from 1944 through 2001) describe the surficial sediments as silt with varying amounts of sand, clay, and organic matter. The silt is typically black with plant and shell fragments.

In summary, the nature and distribution of the sedimentary deposits of the young coastal plain of southwestern Louisiana is closely related to the topographic features formed by the depositional and erosional processes associated with the continental, deltaic, and marine environments within which the coastal plain was constructed (Fisk 1944).

2.3 Regional Flora and Fauna

Calcasieu Estuary has historically provided habitat to abundant wildlife, both aquatic and terrestrial. Lush vegetation (Section 2.3.1) provides forage and protection to numerous terrestrial species (Section 2.3.2) and aquatic species (Section 2.3.3) that populate the marshes and prairies associated with the Calcasieu Estuary and surrounding area. Critical habitat has not been designated for biota in the study area.

2.3.1 Vegetation

Trees once covered nearly all of Louisiana, but since the late 18th century, large areas have been cleared for agriculture, residential, and industrial development. Much of the forestland is covered by second growth or third-growth timber (Neyland 2000).

The bottom hardwoods and cypress region occurs along most of the Calcasieu River in the coastal prairie region from Lake Charles to points north (Neyland 2000). The region is used as pastureland, and for the cultivation of rice and soybean crops.

Regional Vegetation

Common Trees: Cypress, Live Oak, Gum, Elm, Sycamore, Cottonwood, Hackberry, Willow.

Native Grasses: Bluestem, Indiangrass, Eastern gamagrass, Switchgrass, Big Bluestem, Brownseed paspalum.

Marsh vegetation is typically brackish and common herbaceous plants include: *Spartina alterniflora, Distichlis spicata, Juncus* sp. and *Scirpus* sp. In the marshes upstream of the saltwater barrier freshwater herbaceous plants were reported, and include: *Alternanthera philoxeroides, Eichhornia crassipes, Typha latifolia, Potederia cordata* and *Sagittaria* sp. (Neyland 2000).

On the poorly drained land found in the coastal marsh areas south of Calcasieu Lake, grasses and sedges provide primary habitat, typically *Sapium sebiferum* and *Zanthoxylum clava-herculis* (Neyland 2000).

2.3.2 Terrestrial Biota

The southern marshes and swamps of southern Louisiana are the home of a wide variety of animals. White-tailed deer are abundant throughout the state. A few black bears remain in the more remote parts of the swamp; muskrat, mink, and raccoon are also found there. Among the scarce small mammals are the wildcat, gray fox, beaver, otter, and weasel. Correspondence with the U.S. Fish and Wildlife Service (USFWS) in 2001 notes that "there are no federally-listed threatened, endangered, or candidate species within the proposed project area" (USFWS 2001). However, the state bird, the brown pelican, is on the federal endangered species list. Common small mammals include the opossum, cottontail, marsh rabbit, and gray squirrel.

Regional Terrestrial Biota

Mammals: Mink, muskrat, raccoon, opossum, rabbit, squirrel, deer, beaver.

Migratory Water Fowl: Pelicans, ducks, geese, terns, sandpipers, marsh wren, seaside sparrow, wilson snipe.

Reptiles: Alligator, canebreak rattler, copperhead, water moccasin, turtle

More than one-half of the species of birds in North America are resident in the state or spend a portion of their migration there. Species of migratory wildfowl are the most abundant. They include several species of ducks and geese that spend the winter on the tidal marshes along the Gulf Coast. The most common of the state's water birds include the laughing gull, royal tern, brown pelican, and black skimmer. Birds found in the marshes include the marsh wren, seaside sparrow, red-winged blackbird, Wilson snipe, woodcock, and species of sandpipers.

Alligators are common in the southern Louisiana swamps; one was noted in the Lower Calcasieu study area during the RI. Other reptiles in the state include turtles, lizards, and both poisonous and nonpoisonous snakes. The poisonous snakes found in Louisiana are the coral snake, western pygmy rattler, canebrake rattler, copperhead, and water moccasin.

2.3.3 Aquatic Biota

Among the great variety of fish in the waters off the coast are red snapper, menhaden, gar, redfish, drum, sheepshead, jewfish, blue, jack, blue cat, yellow cat, and paddlefish or spoonbill cat. Many of these species are fished commercially in the estuary.

Regional Aquatic Biota

Fish: Snapper, drum, flounder, catfish, bass, gar, menhaden, mullet

Crustacean: Shrimp, crab, clams, oysters

The estuary is a natural hatchery for many of these species. Various species migrate up the protected bayous to spawn and hatch their young. The quiet, less saline upper reaches of the estuary provide habitat for these hatchlings, nurturing them into juveniles. The hatchlings return to the gulf as young adults to complete their growth cycle (USFWS Species Profiles; various years). Species found in the estuary during the RI include grass shrimp, striped bass, blue crab, mullet, and sea trout.

2.4 Hydrogeology

Significant groundwater exists below the site. Within the upper 300 m of Quaternary sediments, local aquifers include a shallow unconfined aquifer and the deeper confined Chicot aquifer. These aquifers typically consist of sand and gravel units separated by clay aquitards (LGS 1984).

The shallow aquifer is comprised of unconsolidated sand units referred to as the 10-, 20-, and 36-foot sands (LGS 1984). Groundwater in this aquifer is unconfined and occurs as shallow as 0.3 to 1 m below ground surface (bgs). Recharge to the shallow aquifer is from infiltration of precipitation, impoundment leakage and commingling of surface water. Groundwater flow, fluctuation, and quality may be influenced by surface water that intercepts the shallow groundwater, as noted in Bayou Verdine, Faubacher Ditch, and Vista West Ditch (PRC 1994).

Water levels in the shallow aquifer are tidally influenced with up to several inches of daily fluctuation. Because of the local influences, groundwater flow directions are irregular and vary seasonally. The groundwater quality is typically poor and unsuitable for domestic use. There are no known water supply wells completed in the shallow aquifer in the vicinity of the study area.

The major regional, hydrologic units for potable water in the Lake Charles area are the 200-, 500-, and 700-foot sands of the Chicot aquifer. These sands, like the units described above are locally named for the approximate depth where they occur. The Chicot aquifer is the primary source of groundwater for public supply, irrigation and industrial use in the area. Yields from wells completed in the 200-foot sand range from 25 to 450 gallons per minute (gpm); in the 500-foot sand from 19 to 3,800 gpm; and in the 700-foot sand from 27 to 2,200 gpm. Specific capacity of the Chicot aquifer ranges from 2 to 23 gpm per foot. The hydraulic conductivity ranges from 40 to 220 feet per day (LGS 1984).

Recharge to the Chicot aquifer is primarily through infiltration of precipitation in outcrop areas in northern Calcasieu Parish. Some hydraulic connection of the 200-, 500- and 700-foot sands is evident, with downward movement of water from the 200- to 500-foot sands and upward movement from the 700-foot sand. The 700-foot sand is recharged from the underlying Evangeline Aquifer (LGS 1984).

Groundwater from the Chicot aquifer 200-foot sand generally occurs at 110 to 120 feet bgs. Water levels in the Chicot aquifer within the Lake Charles area have been steadily declining at a rate of about one foot per year. Heavy pumping in the area has created a cone of depression in the 200-foot zone, such that groundwater flows towards Lake Charles in a concentric pattern from surrounding areas (LGS 1984).

Surface water hydrogeology is integral to each of AOCs (Bayou Verdine, Bayou d'Inde, Upper and Lower Calcasieu) and is therefore discussed in more detail in the following subsections.

2.5 Estuarine Conditions

Calcasieu Estuary is a complex interconnected system of bayous, marshes, open flats, and shallow lakes and dredged ship channels. Flow within specific segments of the estuary is governed by geometry, distance from open water, inflow, total depth, vegetation and tidal influence in the area. Habitat of the areas further defined by water salinity, which ranges from fresh to saline. Section 2.5.1 discusses the various sub-systems and their occurrence within the AOCs.

The estuary receives drainage and discharge from various developed, agricultural, and rural areas. Section 2.5.2 introduces the various industries present in the estuary. The section identifies the areas that may be impacted by industrial discharge or accidental release. A more detailed discussion of these elements is provided below.

2.5.1 Energy Systems

Calcasieu Estuary is made up of five general sub-areas as defined here as energy settings: bayou (ranging from shallow to depth areas), marsh, shallow lake, shipping channel, and river. Energy system classification is primarily based upon flow with a focus on sediment stability; however, as noted above, the overall quality of each area is dependant upon many conditions, and will be addressed by the physical and chemical composition of the areas and evaluation in the human health and ecological risk assessments.

The energy of a specific area influences surface water variability, sediment nature, and stability. Depositional environment, surface water conditions, and stability of the sediment in each area can be used to describe the behavior of the system. In addition, there are areas within the estuary that are considered atypical with respect to their associated physical or chemical characteristics; this system is categorized as "other".

Detail on each of the energy systems, system interaction, and their response to natural and manmade impacts is provided in Section 3.0. The impact of system energy on

chemical fate and transport is discussed in Section 5.0. The following subsections provide a brief overview of the energy systems that comprise the Calcasieu Estuary.

Exhibit 2-1 summarizes the distribution of energy systems in the RI study area.

Exhibit 2-1 Energy System Distribution in the Calcasieu Estuary Study Area

Energy System	Bayou d'Inde	Bayou Verdine	Upper Calcasieu	Lower Calcasieu
Bayou	✓	✓	✓	✓
Marsh	✓		✓	
River			✓	
Shallow Lake			✓	✓
Ship Channel			✓	✓
Other				✓

Bayou

The bayou is the natural tributary to the estuary. The system is typically a low-flow system that serves ultimately as a sediment exporter. The bayous in Calcasieu Estuary receive surface run-off from multiple areas, including industrial, rural, municipal, and agricultural areas. The amount of sediment loading is dependent upon the composition of the bayou drainage area.

Sediments tend to be silty sands to clays and generally become finer upstream. Sediments are generally stable in the upper reaches of the bayou where vegetation is more prevalent, and tidal surge tends to be lowest. Bayou sediments are subject to disturbance under scouring (strong flood tide or high wind) conditions. Sediment stability tends to be lower in shallow segments of the bayou or where sediments are disturbed by traffic. Sediment stability is diminished where the water surface turbulence approaches the sediment surface.

Marsh

Estuarine marshes are typically sediment sinks. They are low energy, vegetated and generally sheltered, slow draining basins. They receive and generally contain sediments due to the higher degree of vegetation within their margins. The low water levels within these marshes make them susceptible to dewatering under wind forcing conditions. Lockport Marsh is grouped with the marshes but differs in the degree of vegetation and the volume of the area that is sheltered or protected from inflow. Lockport Marsh tends to receive flow from the ship channel intermittently under high flow conditions. The remaining areas classified as marsh under this study generally receive less circulation. Lockport Marsh was not grouped with the shallow lakes due to the overall shallow depth and the number of levees that provide protection to the north and eastern areas of Lockport Marsh.

Shallow Lake
Shallow lakes differ from the marshes in overall size. The shallow lakes are generally 1 to 3 meters, with an area of greater than 0.5 square kilometers (km^2). Vegetation within the shallow lakes is generally less than that of the marshes overall; however, substantial biota habitat is present in some areas. The salinity varies from intermediate to saline in the study area.

As with the marshes, the shallow lakes are net sediment sinks. They receive sediment from various sources: overland, terrestrial soil erosion, and water borne sediment transport.

Ship Channel
The dredged portion of the estuary is commonly referred to as the ship channel. The areas include Clooney Island Loop, western Coon Island Loop, the Lyondell West Slip, the PPG North Dock area of Bayou Verdine, lower Bayou d'Inde, and the main ship channel. This energy system is a high flow, deep, wide channel routinely dredged to maintain shipping lanes for large, deep draft vessels. The area is a conduit for increased flood tide surge (flow from the Gulf), and salinity is typically brackish. Flow within the ship channel is generally in the thousands of cubic meter per second compared to the single digit range reported for the upper river and bayous.

River
The rivers designation is the undredged segment of the Calcasieu River, upstream of Lake Charles. The river resembles the low flow bayou, however, larger overall. The river is larger, 15 to 25 m wide and 4 to 5 m deep. The flow is proportionately greater as well. Salinity tends to be fresh to intermediate. The geometry is typical for a meandering stream, with broad elbows that contain finer sediments. The river is located above Lake Charles and is protected somewhat by the lake; however, it is still susceptible to tidal surge and wind forcing.

Other
The other designation is used to describe the Indian Marais Lagoon located on the edge of the Lower Calcasieu ship channel (Figure 2-2). The lagoon is partially open to ship channel flow and currents. It is bermed and does not receive significant overland run-off. The system is not a shallow lake due to its size and lack of vegetation and habitat. Its habitat, geometry, and depth limit its classification as a marsh. It is classified separately as it is connected to the ship channel and is a potential sediment source and exporter.

2.5.2 Industry and Permitted Discharge

In addition to the natural landforms, industry comprises much of the land surface. Over 20 major industrial facilities exist in the area (Figure 2-5) and many have or have had permitted National Pollutant Discharge Elimination System (NPDES) effluent discharge outfalls to the estuary. The NPDES program is administered by the State of Louisiana, as noted in the permit numbers presented below. Some of the facilities do not have permitted discharge facilities but have operations that have had spills or

other releases that potentially impacted the estuary in the past. A summary of the industries, their outfalls, and the region of the estuary where the facility resides are provided in Exhibit 2-2.

Exhibit 2-2 Major NPDES Permitted Facilities and Outfalls

Industry	LPDES Permit Number	Current or Historical Outfalls	Receiving Water
Lyondell/ARCO/ Olin Chemical	LA005347	001, 008, 010, 011, 016, 017, 019, 020, 022, 025 - 030, 032, 033, 034, 410	BV, UC
Conoco Refinery [1]	LA0003026	001 – 050, 101	BV, UC
Conoco – Clifton Ridge	LA0003026	001, 002	LC
Conoco – Coke Handling	LA0003026	001	LC
Conoco – Pipeline[2]	LA0003026	010-013, 103	IM
Condea Vista	LA0003336	001 - 004, 009, 018, 028, 029A, 030, 053, 054, 201, BAC1	BV, UC
PPG	LA0000761	001, 003, 004, 010, 011, 014, 017 - 021, 101, 101A, 103Q, 110, 111, 118, 201, 201A, 301, 401, 501, 501A	BI, BV, UC
Citgo	LA0005941	001 - 004, 006, 006A, 006B, 008 - 010, 106, 011 - 013	BI, LC
Equistar/ OxyChem	LA0069850	001 - 003, 102	BI
Firestone	LA0003824	001, 003, 004	BI
Westlake Polymers	LA0071382	001 - 011, 101, BAC1	BI, LC
Louisiana Pigment	LA0071382	001 - 005A, 101, 101A, 201	LC
Westlake Petrochemicals	LA0082511	001 - 008, 010, 010A, 101 - 104, BAC1	LC

BV – Bayou Verdine, BI – Bayou d'Inde, UC – Upper Calcasieu, LC – Lower Calcasieu, IM – Indian Marais Bayou
LPDES – Louisiana Pollutant Discharge Elimination System permit number
[1] Conoco Refinery primary Outfall 001 was re-routed from BV to the Calcasieu River, just upstream of Clooney Island Loop in June 1997.
[2] Pipeline Outfalls Conoco 001-013 and 103 were reported as active from 1993 through 1998.

Discharge compounds, concentrations, flow, and physical parameter conditions are specified under NPDES. Table 2-1 presents the average and maximum permitted limits for the facilities mentioned in Exhibit 2-2. The NPDES permitting process requires that facilities characterize effluent streams and sources (pre- and post-treatment, as applicable). Once approved, discharge is monitored on a set frequency, measured at compliance points (typically where the outfall empties into surface water although this may vary with flow conditions) and reported to LDEQ and EPA. Flow and/or concentration exceedances require LDEQ notification and initiation of response actions. If the release is a chronic leak or similar long-term release, the LDEQ may require that the owner determine extent of contamination and conduct remediation activities.

2.6 Estuary Areas of Concern

An overview of the characteristics and a description of the physical parameters of each of the energy systems present in the portions of the estuary identified as AOC is provided below. The AOCs are Bayou Verdine, Bayou d'Inde and Upper and Lower Calcasieu. As mentioned previously, the AOC boundaries were developed in the early stages of the RI and were used to group regions of the estuary to aid in evaluation and management of the site. Data is presented by AOC; however, data interpretation is not bound by these groupings. Instead, the information is evaluated by examination of site conditions and the impacts to sediments and sediment stability. Detailed findings for these areas are presented in Sections 7 through 10.

2.6.1 Bayou Verdine

Bayou Verdine is located between the City of Westlake and the community of Mossville, and north-northwest of Lake Charles in Calcasieu Parish, Louisiana (Figure 2-2). Bayou Verdine's headwaters originate in the farmland north of the city of Westlake and flow primarily south-southeast, entering the ship channel on the north side of Coon Island Loop, north of the Interstate 210 (I-210) bridge. Bayou Verdine is approximately 7 km long and is the only major tributary to Calcasieu River-Coon Island Loop (Curry et al 1997) although other industrial discharge also enters western Coon Island Loop directly.

Bayou Verdine

- Energy Systems
  - Bayou
- 7 km long
- Major Industry
  - Conoco
  - CONDEA Vista
  - PPG
  - Sasol
- Undeveloped land
- Documented releases

2.6.1.1 Physical Setting

Relief in the area of the bayou ranges from 1 to 5 m above mean seal level (MSL). The bayou and surrounding area are located within the 100-year and 500-year flood plains of the Calcasieu River Basin (Figure 2-6). Its headwaters are fresh, and, as the water travels downstream, it mixes with intermediate to saline water of the Calcasieu River to the south. According to the USFWS National Wetland Inventory Map, the upper reaches of Bayou Verdine (from point of origin to Interstate 10 [I-10]) are comprised of a palustrine wetland system that is periodically flooded during storm events and a riverine segment that is permanently flooded.

The upper reaches of the bayou have water depths ranging from 0.1 to 1.0 m, and the lower reaches have depths of up to 6 m at the North Dock area. Throughout the Conoco facility and downstream of I-10, water depths are 1.2 to 2.1 m.

Bayou Verdine is tidally influenced throughout, with up to 3 to 6-inches of daily water level fluctuation (U.S. Army Corps of Engineers [USACE] 1976), The bayou has an estimated average rate of flow of approximately 8 cubic feet per second (cfs) in its southern reaches (USACE 1976). Near the confluence of Bayou Verdine and Coon

Island Loop, Bayou Verdine and the shallow groundwater are in direct communication (IT Corporation 1995).

2.6.1.2 Land Use

The land around Bayou Verdine is characterized by undeveloped land, mixed rural, residential, commercial, and heavy industrial use; however, industrial applications predominate in the southern section of the bayou. Permitted industrial discharges to Bayou Verdine under NPDES include those outfalls located on property owned or utilized by Sasol North American Inc. (Sasol) formerly CONDEA Vista Company (CONDEA), Conoco Inc. (Conoco) Lake Charles refinery, and PPG (Figure 2-5). Conoco and PPG each have either material transport, storage, or discharge activities that potentially impact middle to lower Bayou Verdine and/or Coon Island Loop.

Three drainage ditches discharge to Bayou Verdine. The Vista West Ditch passes through Sasol and the northern portions of Conoco; the Faubacher Ditch passes through Sasol and Conoco properties east of the Vista Ditch, both are approximately 1.6 km long (Figure 2-5). Faubacher Ditch begins in the residential area east of Conoco and flows west through Conoco's land treatment area and Sasol's chemical plant. Faubacher Ditch turns south and enters Bayou Verdine at the Conoco Refinery, north of the Kansas City Southern Railroad (KCSRR). The third ditch entering Bayou Verdine is the KCSRR West Ditch, parallel to the railroad tracks, discharging into Bayou Verdine south of Faubacher Ditch. Conoco Outfall 004 discharges into the KCSRR West Ditch. Impacted groundwater has been found in the shallow sand units around the West Ditch (Curry et al 1997).

These drainage ditches are typically narrow 0.1 to 1.0 m, channels with less than 0.5 m of water flowing in them. Historically, analytical data show elevated COPCs in all of the ditches, with the highest concentrations in the Vista West Ditch.

Industrial development along Bayou Verdine has had a significant impact on the local system. During the 1950s, the southernmost 1,000 m of the bayou were rerouted to the west when Olin Corporation (Olin) built the West Pond over the original bayou. The former route of Bayou Verdine downstream of I-10 was to the east of its present course; however, the confluence with the Coon Island Loop was near its present mouth (PRC 1994). Following the initial plant build-up, the only reported dredging on Bayou Verdine was performed by PPG in the North Dock Area (at the confluence of Bayou Verdine and the Coon Island Loop) in 1992. During 1992, the area was dredged to a depth of 6 m to accommodate barge traffic (PRC 1994).

2.6.1.3 Spills and Releases

Uncontrolled industrial releases from the companies along Bayou Verdine have been reported. Various releases from Sasol (formerly CONDEA Vista) chemical manufacturing processes have occurred, potentially impacting Bayou Verdine. Contaminants were primarily 1,2-dichloroethane (EDC) and 1,1,2- trichloroethane (TCA). The releases impacted soil and shallow groundwater, prompting LDEQ to

issue an Administrative Order in 1986 requiring an assessment of the impact of releases at the facility (Curry et al 1997).

Conoco has reported various releases during the facility; history, no significant releases are noted for Bayou Verdine. Chronic periodic releases appear to contribute to the chemical impact to sediments (Pope-Reid Associates/A. T. Kearney, Inc. 1987).

2.6.1.4 Energy System

Bayou Verdine is classified exclusively as a bayou energy system. The bayou is a net sediment exporter, receiving sediments from the undeveloped land to the northwest and from industrial areas associated with Conoco, Sasol, and PPG. Flow in Bayou Verdine is generally sustained by runoff from industrial sources with minor run-off from municipal, agricultural and rural residential areas. Shallow groundwater appears to enter the bayou under gaining stream conditions (IT Corp. 1995). The upper portions of the bayou are generally undisturbed in geometry and vegetation; the lower reaches have been re-routed as noted above, creating an industrial canal. The lower portions of Bayou Verdine are not routinely dredged. Overall, Bayou Verdine is a low-flow system.

At the confluence of Bayou Verdine and Coon Island Loop, the bayou discharges into a moderately swift, deep channel, which is a conduit for brackish to saline water from the ship channel. The engineered confluence is wider than the natural opening and allows for greater tidal influence and storm surge up the bayou.

Sediments within Bayou Verdine tend to be silts and silty sands. This appears to be the combined result of overland soil erosion. In addition, black coke fines from the Conoco Refinery are widespread in the lower portion of the bayou. Sediments in the upper reaches of the bayou tend to become finer grained, indicating the approximate extent of tidal surge deposition.

Development along Bayou Verdine has defined the current nature of the bayou. Industrial discharges (current and historic), accidental releases, and stormwater runoff have contributed to organic and inorganic impacts to surface water, sediment, and biota within the bayou.

2.6.2 Bayou d'Inde

Bayou d'Inde is located in the northern portion of the Calcasieu Estuary, west of the City of Lake Charles, Louisiana (Figure 2-5). Bayou d'Inde's headwaters originate in the western part of Sulphur, Louisiana and flow primarily east-southeast through heavy commercial and industrialized areas before emptying into the ship channel southwest of Coon Island. The confluence of Bayou d'Inde and the ship channel is a large shallow flat are called Lockport Marsh. The area is approximately 1.2 km^2. Substantial mixing of water from Bayou d'Inde and the ship channel likely occurs in Lockport marsh, given the low-lying levees separating these features. Areas in the northeastern portion of Lockport Marsh appear to be protected from significant mixing, based upon the physical and chemical nature of the sediments.

2.6.2.1 Physical Setting

Bayou d'Inde is approximately 15 km long and is a major tributary of the Calcasieu River (Curry et al 1997). The bayou, which originates near the I-10 bridge in Sulphur, has a drainage area of over 1,000 acres (PRC 1993). Bayou d'Inde has both bayou and marsh energy systems. The confluence with the ship channel is a major factor in sediment erosion and deposition. Several smaller tributaries, the largest of which is Maple Fork, located between the PPG Canal and Louisiana Highway 108 (LA-108), join Bayou d'Inde. The second identifiable fork is the upper fork, or headwaters, located to the west and north of LA-108.

Bayou d'Inde

- Energy Systems
  - Bayou
  - Marshes
- 15 km long
- Major Industries
  - PPG
  - Citgo
  - Firestone
  - Westlake Polymers
  - Equistar/OxyChem
- Undeveloped land
- Documented releases

The surface elevation in the area of the bayou averages about 3.1 m above MSL. The area surrounding Bayou d'Inde is located within the 100-year and 500-year floodplains of the Calcasieu River Basin (Figure 2-6). Bayou d'Inde headwaters are typically fresh. These waters mix with intermediate to saline water from the ship channel in the lower sections of the bayou. Bayou d'Inde flows through several small fringe marshes near Maple Fork Bayou. These marshes are typical estuarine fringe marshes, with generally intermediate surface water salinities.

Geometry of the lower portions of the bayou includes a width that ranges from 24 to 46 m wide and 2.5 to 5 m deep and is tidally influenced with up to 3 to 6- inches of daily water fluctuation (USACE 1976). Depth is greatest from the ship channel to LA-108 where the bayou has been dredged to accommodate barge traffic. The remainder of the bayou is relatively shallow. It is subjected to tidal surge, varying salinity effects, and turbulence due to barge traffic. Significant bottom scouring (flood tide currents) during periods of salt-wedge salinity stratification have been noted in the deeper portions of the bayou. Salinity can vary significantly and is dependant upon season, rainfall, tide, recent storm surge, winds, and other conditions. Upper reaches above LA-108 are typically low-flow areas.

Lockport Marsh is a low-lying, intermediate to brackish broad shallow area with water depth generally less than 1 m. Lockport Marsh is subject to overbank flow from PPG Canal to the west, Bayou d'Inde from the south, and the ship channel to the east during periods of high wind or water flow. Vegetation is limited, and combined with the less protected nature of the southeastern portion of the area, flow through the area can be significant. Lockport Marsh is considered a marsh by name and is grouped with the remaining fringe marshes in Bayou d'Inde due primarily to its shallow depth and protected nature of the upper portion of the area.

2.6.2.2 Land Use

The land around Bayou d'Inde includes undeveloped wooded marshland, rural residential, commercial, and heavy industrial properties. Rural residential and undeveloped woodland areas border the bayou northwest and upstream of the industrial area. Heavy industry dominates the area bounded by the PPG Canal and LA-108. Several of these industries have wastewater outfalls permitted under NPDES. Permitted industrial discharges to Bayou d'Inde include outfalls owned or utilized by to Citgo Petroleum Corporation (Citgo), Equistar/OxyChem Corporation (Equistar/OxyChem), Firestone Synthetic Rubber and Latex Company (Firestone), Westlake Polymers Corporation (Westlake Polymers), Certain-Teed Products Corporation (Certain-Teed), and PPG, which all enter Bayou d'Inde (Figure 2-5). The NPDES permitted discharges vary; however, the largest flow appears to be from the PPG canal, with a design capacity of 233 million gallons per day (MGPD).

2.6.2.3 Spills and Releases

Various releases to the bayou have occurred. Some of the more significant releases, with potential to impact Bayou d'Inde, are noted below.

PPG operated earthen ponds in the south terminal area at the east end of the PPG canal that received "kettle" bottom wastes. These wastes contained hexachlorobutadiene (HCBD), hexachlorobenzene (HCB), EDC and other organics. Leachate from the ponds drained to the PPG Canal. The pits operated from the mid 1960s to late 1970s when the ponds were closed. Groundwater has been impacted and remedial actions were initiated by PPG in the early 1980s (PPG 1989).

PPG operated a mercury-settling pond in the early 1970s to treat Mercury Cell Chlorine Unit wastewater. The unit was an unlined earthen pond (IT Corp. 1992). Various operations related activities are referenced in the literature and may have impacted the upper reaches of Bayou d'Inde between Little Bayou d'Inde and LA-108. In general, long-term, or chronic releases to the bayou appear to be the primary impact to sediments in Bayou d'Inde.

2.6.2.4 Energy Systems

Bayou d'Inde contains two energy systems, bayou and marsh. The bayou is divided into an upper residential area and a lower industrial region. The upper segment extends from the headwaters to just above the LA-108 Bridge. The industrial segment extends from LA-108 to the confluence with the ship channel. Marshes are present in Bayou d'Inde, a series of small intermediate marshes located near Maple Fork and in Reach 2 of Bayou d'Inde. Lockport Marsh, located at the confluence of Bayou d'Inde and the ship channel, is identified as a marsh but differs primarily due to periodic flow through the lower portion of the area. Classification as a marsh is based upon the shallow depth and the relatively isolated areas in the northeastern portion of Lockport Marsh.

The bayou contains both natural and modified segments; however, the geometry and depth of the natural channel has generally been maintained. The lower segment of

Bayou d'Inde from the PPG Canal to the ship channel has been dredged in the past. The bayou is characterized by low-flow conditions and moderate vegetation. Salinity varies from intermediate to brackish.

Industrial development along the lower segments has affected the system, namely by the introduction of barge traffic and moderate dredging; however, the primary characteristics of the energy system are intact. Westlake Polymer barge traffic traverses the lower segment from the ship channel to their dock located at LA-108. Barge traffic up Bayou d'Inde is a source of turbulence, mobilizing finer grained sediments, due to the overall shallow depth of the bayou. The shallow depth of the traffic zone is a primary element in re-suspension of these sediments. Transport of the suspended material is affected by many factors as discussed in Section 5.0.

Sediments within Bayou d'Inde are generally silty sands. This appears to be the combined result primarily of overland soil erosion and deposition of reworked material from the ship channel in the lower section. Bayou d'Inde sediments are generally coarser than Bayou Verdine, due in part to the broader confluence with the ship channel and deeper (dredged) bayou. Sediments in the area above LA-108 tend to become finer grained silts, indicating the general extent of tidal surge. Typical interaction of the energy systems is discussed in Section 3.0.

Development along Bayou d'Inde has altered the natural setting in the industrial area. Industrial discharges (current and historic), accidental releases, and stormwater runoff have contributed to organic and inorganic impacts to surface water, sediment, and biota within the bayou.

2.6.3 Upper Calcasieu

The Upper Calcasieu area is defined as that region of Calcasieu Estuary that extends from the saltwater barrier on the Calcasieu River north of Lake Charles and flows southwest into Lake Charles, west to Clooney Island Loop, and southwest to approximately 155 m south of Coon Island Loop (Figure 2-5). Coon Island Loop connects with the ship channel near the I-210 Bridge.

2.6.3.1 Physical Setting

The Upper Calcasieu area is approximately 25 km in length and receives discharges from several sources along its banks. Bayou Verdine and Contraband Bayou are the two major tributaries that discharge into the Upper Calcasieu area.

The surface elevation in the area around Upper Calcasieu averages about 3 m above MSL and the area is located within the 100-year and 500-year floodplains of the Calcasieu River Basin (Figure 2-6). The Calcasieu River above Lake Charles ranges from 62 to 372 m wide. Lake Charles is approximately, 1,860 m wide.

Upper Calcasieu

- Energy Systems
  - River
  - Marsh
  - Ship channel
  - Shallow lake
  - Bayou
- 25 km long
- Major Industries
  - Lyondell/Olin
  - Montell
  - Conoco
  - PPG
- Undeveloped land
- Documented releases

The ship channel depth ranges from 4.6 to 14 m in depth below the I-10 Bridge. Sampling of the ship channel was limited to the shallow (4.6 m) shelf as the USACE routinely dredges the deeper portions of the ship channel. Periodic dredging is required to remove accumulated sediments and debris, maintaining the ship channel at its authorized depth (USACE 1976).

Water in Upper Calcasieu is intermediate to brackish and tidally influenced. Salinity stratification is noted during periods of the year, controlled primarily by density driven flow as a result of tidal influence and salinity stratification. Density-driven flood tide (upstream flow) currents have been observed regardless of tide stage in previous studies (DeRouen and Stevenson 1987). Dredging of the ship channel through to the Port of Lake Charles has accentuated these effects. A salinity control structure was installed by USACE in 1968. The saltwater barrier is a tainter gate structure constructed in a short channel 17 m wide. The sill of the structure is 4 m below mean low Gulf level. The barrier is operated between March and October, with navigation and retaining structures closed, except for vessel passage. From October to February, periods of generally high water levels, the gates are open allowing free flow of water. The saltwater barrier effectively protects the upper Calcasieu River from saltwater intrusion. The barrier effectively divides the river into an upstream, fresh water system and a downstream, estuarine system. The extensive river modifications have resulted in a complex system of interlaced natural and artificial barriers, channels, marshes, and lakes.

2.6.3.2 Land Use

Land use of properties along the Upper Calcasieu segment of Calcasieu Estuary is rural, residential, municipal, and industrial. Bayou Verdine receives discharge from several industrial properties, as noted above, and discharges at the northern end of Coon Island Loop. Contraband Bayou receives Lake Charles municipal wastewater discharge and enters the ship channel between Clooney and Coon Island Loops, passing through primarily residential and light industrial properties (Curry et al 1997).

2.6.3.3 Spills and Releases

Permitted discharge and uncontrolled spills and releases have occurred within Upper Calcasieu. Industrial development along Clooney Island and Coon Island Loops is extensive. Residential and rural development surrounds the upper river, Lake

Charles and Contraband Bayou. Numerous permitted NPDES outfalls enter Upper Calcasieu as follows:

- Clooney Island Loop – Lyondell/Olin Industries, Inc. (Lyondell) and Conoco
- Contraband Bayou – Publicly owned treatment works (POTW) discharge from the City of Lake Charles
- Coon Island Loop - Conoco, Lyondell/Olin, PPG, and Sasol

Various releases to Upper Calcasieu have been reported, some of the more noteworthy are presented below.

The most notable are two EDC releases that occurred at the Conoco facility in 1987 and 1994. In 1987, an EDC (alias 1,2-dichloroethane [1,2-DCA]) release occurred in the southwestern portion of the facility. The release was the result of a crack in the sump of a storage tank. The crack has since been repaired. In 1994, a release of EDC was discovered in the northwestern part of the property from a leak in a pipeline following an unloading event. Emergency response actions were initiated which included removal of contaminated soil and water from a stormwater drainage ditch. Sediments [in Bayou Verdine] were sampled and impacted sediments were dredged.

Vista Chemical has released EDC and TCA from the Vinyl Chloride Monomer (VCM) Unit that has impacted media in Vista West ditch and Bayou Verdine. The extent of contamination has been assessed by CONDEA in response to an Administrative Order issued by LDEQ in 1986. Impacted water and sediments may have entered Coon Island Loop in Upper Calcasieu.

2.6.3.4 Energy Systems

Upper Calcasieu is a diverse segment of the estuary that consists of an element of every energy system present in Calcasieu Estuary. The AOC contains natural river, marshes, shallow lake areas, bayou, and shipping channel.

The river is approximately 17 m wide and 4.6 m deep. Salinity in the upstream segment is generally fresh and is controlled by the saltwater barrier. The river experiences moderate tidal fluctuation. Flood tide currents (upstream flow) have been observed throughout the segment during salinity-stratified conditions. This density-driven current generally increases salinity in the area and makes the segment a net sediment exporter (DeRouen and Stevenson 1987). Coon Island Loop and Clooney Island Loop and the ship channel represent the dredged, brackish, salt-wedge salinity regime portion of Upper Calcasieu.

The Lake Charles area (undredged, natural lake portion) is generally shallow and is a net sediment sink. The western side of the lake, where the river is dredged, increases flow, salinity and tidal influence. Tidal activity and salinity generally increase downstream throughout the area.

Contraband Bayou is a low-flow natural bayou that receives discharge from the Lake Charles POTW. The geometry of Contraband Bayou allows for moderate tidal fluctuation and intermediate to saline salinity conditions.

Sediment character is as diverse as the energy systems. Section 9.0 provides details on the condition of sediments in Upper Calcasieu. Discharges (current and historic), stormwater runoff, and accidental releases (documented and undocumented) have contributed to organic and inorganic impacts to surface water, sediment, and biota within Upper Calcasieu.

2.6.4 Lower Calcasieu

The Lower Calcasieu study area comprises the portion of Calcasieu Estuary from the I-210 bridge, just south of Coon Island Loop, to the outlet of Moss Lake – a distance of approximately 15 km (Figure 2-5).

2.6.4.1 Physical Setting

Lower Calcasieu is characterized predominantly by the ship channel interconnected to shallow lakes and small lagoons. The ship channel is 125 m wide and 15 m deep and is routinely dredged (USACE 1976). Prien Lake is located on the east side of the ship channel; the mouth of the lake is located across from Lockport Marsh. The lake runs parallel to the ship channel, re-entering the ship channel north of Indian Marais Lagoon. Prien Lake lies within the old channel of the Calcasieu River. The Prien Lake segment is approximately 4.8 km in length.

Lower Calcasieu

- Energy Systems
  - Ship channel
  - Shallow lake
  - Bayou
  - Other (Indian Marais)
- 15 km long
- Major Industries
  - Citgo
  - W.R. Grace
  - OxyChem
- Undeveloped land
- Documented releases

Indian Marais Lagoon has a 230,000-kiloliter capacity and is partially contained within an earthen embankment built-up along the west side of the ship channel midway between Prien Lake and Moss Lake. Indian Marais Lagoon received flow from Citgo Outfall 003, the primary refinery wastewater outfall until 1992, when Outfall 003 was re-directed directly to Calcasieu River. The lagoon is about 3 m deep, with a 300 m pier separating it from the ship channel. The lagoon is partially bermed (2 to 3 m) and may occasionally receive stormwater run-off. The lagoon is in communication with the ship channel and is subject to sediment scouring during high tides.

Moss Lake flows into the ship channel from the west and is fed by Bayou Olsen. Bayou Olsen drains the area south and west of Bayou d'Inde. The Bayou Olsen and Moss Lake segment is approximately 9.6 km in length.

Elevation in the lower portion of the Calcasieu Estuary ranges from 1.6 to 4.6 m above MSL. The area surrounding Lower Calcasieu is located within the 100-year and 500-year floodplains of the Calcasieu River Basin (Figure 2-6).

2.6.4.2 Land Use

Much of the adjacent land in the Lower Calcasieu study area is undeveloped, but several industrial facilities (Citgo and W.R. Grace and Co.) have outfalls to the ship channel between Prien Lake and Moss Lake. Citgo owns and operates the Lake Charles Complex located along the west bank of the Calcasieu River south of Bayou d'Inde. The Citgo lubrication plant is located in the northwest portion of the refinery. Equistar/OxyChem, which operates the Citgo propylene fractionation unit, is located in the northeast portion of the refinery property.

W.R. Grace operates a manufacturing facility located on the west side of the ship channel, south of Citgo. The facility produces silica-alumina petroleum cracking catalyst. Facility surface drainage is to the south to Bayou Olsen.

The ship channel is used extensively throughout Lower Calcasieu, providing transport to over 40 million tons of product annually. The channel is dredged to 125 m wide and 15 m deep (USACE 1976). Dredging of the ship channel is routine and occurs on average about every 2 to 4 years. The USACE maintains the design geometry of the channel to accommodate large, deep draft vessel passage. Design of the ship channel in Lower Calcasieu has remained constant since the channel was enlarged to its current size in the 1960s.

2.6.4.3 Spills and Releases

Various industrial releases have occurred within the Citgo and Equistar/Oxychem complex on the west side of the ship channel. Soil and groundwater have been impacted, and the facilities monitor several areas. The most significant potential impact to Lower Calcasieu appears to be from impacted sediments in Indian Marais Lagoon. Sediment stability when the lagoon is in direct communication with the ship channel during storms or other high-energy conditions may be impacted.

2.6.4.4 Energy Systems

The Lower Calcasieu area contains four energy systems: shallow lakes (Prien and Moss Lakes and the areas to the south of Prien Lake and east of the ship channel), low-flow bayou (Bayou Olsen), the ship channel, and Indian Marais Lagoon. Indian Marais Lagoon is considered a sediment source and is susceptible to sediment scouring and breaching, thereby acting as a sediment source.

The ship channel is a high flow, tidally influenced saline environment. The channel is routinely (every 2 to 4 years) dredged to clear accumulated sediment and debris. Increased water salinity and vegetation losses have weakened soils, leading to increased sloughing.

Prien Lake is located on the east side of the ship channel; the mouth of the lake is located across from Lockport Marsh. The lake runs parallel to the ship channel, re-entering the ship channel north of Indian Marais Lagoon. Rhodamine dye tests indicate that Prien Lake receives flow from the mouth of Bayou d'Inde (Curwick 1988). Flow through Prien Lake may exit through two openings to the ship channel;

however, flow rates through the shallow lake are low and the geometry is such that circulation is limited. The Prien Lake segment is approximately 4.8 km in length.

Indian Marais Lagoon has a 230,000-kilometer capacity and partially contained within an earthen embankment built-up along the west side of the ship channel midway between Prien Lake and Moss Lake. The former lagoon is open to the ship channel via a bridge pier approximately 300 m long. The lagoon is bermed with an embankment (2 to 3 m high) that separates Indian Marais Lagoon from the surrounding area.

Moss Lake flows into the ship channel from the west and is fed by Bayou Olsen. Bayou Olsen drains the area south and west of Bayou d'Inde. Moss Lake is generally a higher flow body with greater circulation and tidal influence. The Bayou Olsen and Moss Lake segment is approximately 9.6 km in length. The bayou is generally a vegetated low-flow system. The bayou is subject to tidal surge, and salinity is brackish.

Overall, Lower Calcasieu is tidally influenced, with 6 to 12 inches of daily fluctuation (USACE 1976). Salinity stratification tends to be density driven and seasonal. Observations during the RI indicated a mixed salinity regime; however, during warmer months, a salt-wedge regime has been reported (Duke 1985). Density-driven flood tide (upstream) currents have been noted along the bottom of the ship channel, generally 6 m below the surface (Duke 1985; DeRouen and Stevenson 1987). Salinity of the Lower Calcasieu area surface water ranges from brackish to saline.

These systems are interconnected, yielding a network of sediment sources, transports, and sinks. The higher salinities and geometry of Lower Calcasieu tend to make this portion of the estuary a net sediment transporter, as is evidenced by contaminant occurrences noted in Section 10.0 of this report.

2.7 Climate

The climate in Calcasieu Parish is humid and temperate and is influenced by its proximity to the Gulf of Mexico. The average year-round temperature is 68°F, with an average daily high of 78°F and an average daily low of 58°F. The hottest months are July and August with average high and low temperatures of 91°F and 73°F, respectively. The average high and low temperatures for the coolest months, January and February are 63°F and 41°F, respectively (NOAA 2002).

Precipitation is relatively uniform from year to year. The average annual precipitation is 54.05 inches, with an average number of 103 rainy days National Weather Service ([NWS] 1999). May, June, and July typically experience the most precipitation, whereas March and October are the driest months. Average monthly precipitation is

Climate Highlights

Average Annual Temperature: 68°F

Average Annual Precipitation: 54.05 inches

Hurricane Season: June - November

approximately 4 inches per month. The average wind speed is 8.6 miles per hour, from the south.

Hurricane season officially runs from June 1st to November 30th. The Gulf Coast is vulnerable to hurricanes because of its proximity to tropical waters and because the warm water of the Atlantic Ocean and the Gulf of Mexico facilitate storm growth. The last hurricane to actually traverse Lake Charles was Hurricane Audrey in 1957. From 1886 through 1997, 71 tropical storms, 34 of which were hurricanes, came within 150 nautical miles of Lake Charles (NWS 1998).

2.8 Dredging History

Calcasieu Estuary has undergone significant engineering modifications centered on creation of the ship channel. These changes were enacted to allow larger barges and ships access to Lake Charles and portions of the river for trade and industrialization. The primary events were the widening of Calcasieu Pass to the Gulf of Mexico in 1871, the construction of the Calcasieu Ship Channel from Lake Charles to the Intracoastal Waterway in 1926, and the construction of the ship channel from Calcasieu Lake to Calcasieu Pass in 1938 (USACE 1976).

In 1946, the ship channel was enlarged to about 10 m deep and 80 m wide. In the 1960s, the ship channel was again enlarged, widened to about 130 m, and bottom depth increased to 15 m (USACE 1976).

In 1970, the western side of the Coon Island Loop (2,300 linear meters) was deepened to 10 m. The channel was widened to 80 m, and the turning basin at the dock area was enlarged to 250 by 330 m (USACE 1976).

Because of channel development, saltwater intrusion into the upper reaches of the estuary became a problem; thus, a saltwater barrier was constructed north of Lake Charles on the Calcasieu River.

2.9 Reference Areas and their Characteristics

Reference Areas Sampled
Willow and Johnsons bayous
Bayou Bois Connine and Grand Bayou
Bayou Choupique

A total of five areas were sampled to represent reference conditions within the Calcasieu River watershed and surrounding environments (Figure 2-7). These areas include Johnsons Bayou, Willow Bayou, Bayou Bois Connine, Grand Bayou, and Bayou Choupique. Willow and Johnsons bayous drain into Sabine Lake while Bayou Bois Coninne and Grand Bayou drain into Calcasieu Lake. All of the reference areas are south of the Intracoastal Waterway, with the exception of Bayou Choupique.

The reference areas represent the bayou energy system. Bayou Bois Coninne and Grand Bayou are similar to Bayou Verdine and Contraband Bayou. While Bayou Choupique and Johnsons Bayou have been dredged by the USACE in the past, they

are the deepest waterways, ranging from approximately 2.5 to 3 m and are comparable to Bayou d'Inde. Salinities vary in the reference areas as they do in the study area, subjected to the same wind forcing, tidal surge and temperature driven density changes. Sediments composition is similar as well. Reference areas were added to the RI to provide "background" bayou areas for comparison. All five of these reference areas are relatively pristine and have been virtually unaffected by industrial activities (Ramelow et al. 1987). The following sections provide a brief overview of area characteristics.

2.9.1 Willow Bayou and Johnsons Bayou

Willow Bayou and Johnsons Bayou are located in Cameron Parish along the southeast edge of Sabine Lake and are within the Sabine National Wildlife Refuge (SNWR) (Figure 2-7). SNWR is a major nursery area for estuarine-dependent marine species (i.e., shrimp, crab, menhaden, redfish, etc.), as well as being the habitat for alligators and other reptiles, mammals, and numerous water, wading, and marsh birds. The area is comprised of marsh meadows and shallow brackish marshes. The dominant plants are Marsh hay and Gulf cordgrass, Three-square, Leafy three-square and Spikerushes. Public use includes recreational boating, fishing, and wildlife observation.

Johnsons Bayou is located 102 km southwest of Lake Charles on LA Highway 82. Willow Bayou is located approximately 0.5 km north of the mouth of Johnsons Bayou and is only accessible by boat via Sabine Lake. Both Willow Bayou and Johnsons Bayou are tributaries to Sabine Lake and discharge into the lake along its southeastern shoreline.

2.9.2 Bayou Bois Connine and Grand Bayou

Bayou Bois Connine and Grand Bayou are located on the southeast side of Calcasieu Lake approximately 48 km south of Lake Charles in Cameron Parish (Figure 2-7). Bayou Bois Connine and Grand Bayou provide habitat for estuarine-dependent marine species (shrimp, crab, menhaden, redfish, etc.), as well as being the habitat for alligators and other reptiles, mammals, and numerous water, wading, and marsh birds. The bayous are in a shallow marsh area, with the dominant plants being [Leafy three-square and Spikerushes]. Public access in these areas is restricted, with some of the property privately owned, but human activities include hunting and wildlife observation.

Bayou Bois Connine and Grand Bayou are tributaries to Calcasieu Lake, emptying into the lake along its eastern shore. Both bayous are joined to the Calcasieu Lake via USACE locks to help prevent saltwater intrusion upstream in the bayou. Access to both Bayou Bois Connine and Grand Bayou is limited to travel by boat, via canals.

2.9.3 Bayou Choupique

Bayou Choupique is located off the Intracoastal Waterway, with the mouth of the bayou between LA Highway 27 and the ship channel (Figure 2-7). The bayou is

mostly dominated by sawgrass vegetation. Land use is predominantly residential. The bayou is the habitat for estuarine-dependent marine species (shrimp, crab, menhaden, redfish, etc.), as well as providing habitat for alligators and other reptiles, mammals, and numerous water, wading, and marsh birds. Public use includes recreational boating, fishing, and wildlife observation.

Bayou Choupique was dredged in 1954. Modifications included 4.3 km of channel enlargement, 4 km of diversion channel between the Intracoastal Waterway and river, and construction of the automatic drainage gate in the diversion channel near its mouth to limit saltwater intrusion into the bayou through the diversion channel (USACE 1998).

2.10 Demographics

Calcasieu is one of the 64 parishes (counties) in Louisiana. Calcasieu Parish has a land area of 2,775 km^2 and is part of the Lake Charles Metropolitan Area, with a census 2000 population of 183,577-ranked 7th in the state (U. S. Bureau of the Census 2000). Table 2-2 provides a summary of the local demographics. Other principal cities and towns in the parish include Sulphur, Westlake, and Mossville (Figure 2-8).

The largest employers in 2000 (Table 2-2) were the educational, health, and social services industry, 19.9 percent; the manufacturing industry, 14.9 percent; the retail trade industry, 11.5 percent; the art, entertainment, recreation, accommodation, and food services sector, 11.5 percent; and construction industry, 9.3 percent. Table 2-3 provides a summary of the economic characteristics of Calcasieu Parish.